# SPALLANZANI:

## A PHYSIOLOGIST OF LAST CENTURY.

AN ADDRESS

AT

THE OPENING OF THE MEDICAL SESSION OF THE UNIVERSITY OF GLASGOW,

20*th OCTOBER*, 1891.

BY

JOHN G. M'KENDRICK, M.D., LL.D., F.R.SS.L. & E., F.R.C.P.E.,

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It is the custom of this University to open the Winter Session in the Faculty of Medicine by a public address; and the speaker is left at liberty to select any subject he may consider appropriate to the audience and to the occasion. In availing myself of this liberty, I might address, in particular, those of you who are about to begin the study of medicine, and enlarge upon the nature of the studies in which you will soon be engaged, tendering such advice as experience has taught me might be valuable; or I might speak more directly to those who have already spent one or more sessions at the University, and who might be more interested in a discussion of recent advances in the science and art of medicine; or, lastly, I might endeavour to enlist the attention of those members of the public who honour us by their presence on this occasion.

The object of these annual addresses is to excite in all of us, teachers and students, earnestness and enthusiasm in the pursuit of knowledge, so that we may assemble to-morrow in our class-rooms with

spirit and verve for the coming winter months. In casting about during the autumn for a topic fitted thus to stimulate as well as to interest, it occurred to me that I might bring before you the life and work of a great Italian physiologist of last century, Lazarus Spallanzani, whose researches made a deep impress on science, by touching some of its most profound problems, and whose whole career was one of devotion to the pursuit of truth. It is characteristic of science that the names and lives of the large majority of her votaries are soon forgotten. Only one here and there has his name and deeds inscribed in large letters on the temple of fame, so that future generations may know who he was and what he did; the great majority of the humbler workers are known only to the scientific historian. Time dulls the brilliancy of the fame of even great discoverers. The truths they established become incorporated with science, and are often lost sight of in the advances made since their time, with the result that we forget how much such men really accomplished. The men of each period are apt to exaggerate the importance of the discoveries of their own epoch, forgetting that the labours of others made these discoveries possible by laying the foundations on which they rest. It is, therefore, a wholesome exercise sometimes to survey the past; and one of the best ways of so doing is to study the science or literature of a period, or the works and life of a representative man. This historical method not only increases our reverence for the works of our ancestors, but it gives us more just views of the science and literature of our

own time. It enables us to see everything in true perspective. It saves us from cut and dry, matter of fact, and lifeless text-book science, and it lifts us into a higher plane, showing us the methods of science, the causes of failure, and the secrets of success. Science also becomes, if I may use the expression, more human, when we associate its triumphs with living personalities, with men like ourselves.

These considerations, then, have led me to select Spallanzani as a man representing the state of physiological science, and indeed of general science, in last century. I shall not merely give you an outline of his chief discoveries, but I shall attempt, what is more difficult, to indicate in the briefest way how far our knowledge has advanced since his time as regards some of those problems on which he shed the light of his genius. In the time at my disposal I can only sketch the outlines of this historical picture, leaving you to fill in the details as your knowledge of science advances.

Spallanzani was a native of Italy, a country which during the greater part of last century was often devastated by war, and in which, one would imagine, art, literature, and science would have found it difficult to maintain an existence. Strange as it may seem, however, this was not the case. Although the political aspect of affairs was one of the saddest possible; although Italy, during the 18th century, was the favourite battle-ground of Frenchmen, Spaniards, and Austrians; although the rights and liberties of the

peoples of her states were tampered with; although the states were freely transferred from one tyrannical rule to another without the wishes of their inhabitants being even nominally consulted; although the University towns were often occupied by hostile armies, and their streets echoed with the tramp of soldiers; still, in the midst of all this turmoil, the light of science was never extinguished. The Universities of Bologna, Pavia, and Modena (on the model of which our own University was founded by Pope Nicholas V.) had professors and students even in these troublous times, and there was repose in their old courts and libraries and class-rooms. For this we cannot be too thankful.

Spallanzani was born on 10th January, 1729, at Scandiano, a small town about seven miles from Reggio and fourteen from Modena. He was the son of an advocate, and of good family on both sides of the house. At the age of fifteen, he was sent to a Jesuit College at Reggio, and his rapid progress in rhetoric and philosophy attracted the attention of the Dominicans, who endeavoured, unsuccessfully, to attach him to their order. It is a fact observed in biographical literature that a great man not unfrequently owes much to the personal influence of his mother. There is no trace of this in the case of Spallanzani; but it is recorded that his taste for science was early formed by his association with Laura Bassa, a lady cousin of his own, who was then a Professor in the University of Bologna, and who was celebrated throughout Italy for her genius, eloquence, and knowledge of mathematical and natural science. In these early days

the problem of the higher education of women had apparently been solved, and sex was not considered even in the choice of a professor. Several chairs were then occupied by ladies, and we may take it that they were as charming as they were learned, for Spallanzani himself tells us that, some years afterwards, when he was appointed to a chair in Modena, he had, in accordance with custom, to defend a thesis which was opposed, amidst applause, by his cousin Laura Bassa, "with all the graces of an amiable woman, and the wisdom of a profound philosopher."

After several years spent in the study of the ancient languages and of philosophy, he conformed to the wishes of his father and took up jurisprudence, but the proverbial dryness of this study repulsed him, and acting on the advice of his countryman, Vallisnieri, then Professor of Natural History at Padua, he relinquished law and devoted himself to mathematics and natural history. He also joined the ranks of the clergy, taking the title of Abbé, but he remained unattached, and never undertook clerical duties.

At the age of twenty-six he became Professor of Logic, Mathematics, and Greek in the University of Reggio. During the six years in which he occupied this position, he devoted much of his spare time to the study of natural history. In 1760, at the age of thirty-one, he was transferred to the Chair of Natural History at Modena. Here he remained for eight years, and, in 1768, the Empress Maria Theresa invited him to deliver lectures on natural history in the University of Pavia. He does not appear

to have been appointed to the Chair of Natural History in that University until the death of its occupant, Antonio Vallisnieri, in 1785. At Pavia he laboured assiduously for fourteen years, producing, in rapid succession, those great contributions to science that have made his name famous. During this period, also, and in times when travelling was both difficult and dangerous, he made journeys to Switzerland, the Mediterranean, Sicily, and Constantinople, and he enriched the Museum of Natural History of his University with extensive collections of plants, animals, and minerals. Spallanzani, as I have said before, was a representative man of science of last century. His works were translated into several languages, he was the friend and correspondent of the celebrated men of the day, and he was a member of most of the academies and learned societies. He died on the 3rd of February, 1799, having just completed his 70th year.

Such are the main facts of Spallanzani's uneventful life, as one can glean it from the scanty notices of biographers. Senebier tells us that he was a short-necked high-shouldered man of the middle size, rather inclined to stoutness; his gait was stately and firm; his countenance dark and pensive. He had a high forehead, lively black eyes, a brown complexion, and a robust frame. Ardent in study, he was no recluse, for we are told that he was fond of society, especially of the young, and more especially still of ladies in whom grace and beauty were combined with a refined taste and a love of literature and science. He excelled in hunting and fishing, especially in the latter, and in early life his favourite

recreations were chess and football. We may thus be able to form some conception of Spallanzani as a man; now, let us inquire, what were those discoveries which have given him a prominent place in the history of science? One of his contemporaries, Charles Bonnet, says of him:—"Vous avez découvert plus de vérités en cinq ans que des académies entières en un demi-siecle."

One of the first subjects to which Spallanzani directed his attention was the generation of living beings. He was led to this by the study of a well-known work—*Contemplatións de la Nature* of Charles Bonnet, then Professor of Natural History in Geneva. In this work Bonnet discussed with much acumen the problem of the origin of vitality, and indicated that it was by a study of the minute living beings revealed by the microscope that we might hope to contribute to its solution. Nearly a century and a half had passed since the invention of the microscope in 1590. For many years this instrument was little more than a scientific toy, and it was not until 1675 that it revealed to the astonished gaze of Leeuwenhoek small living and moving forms in stagnant water and in fluids obtained from the bodies of various animals. In 1683, Leeuwenhoek saw, for the first time, organisms taken from the teeth of an old man, which we now recognize as bacteria; and considering the simple microscope he used—a bead of glass fixed in an ivory frame—the description he gives of their appearance and movements is singularly accurate. Undoubtedly those bodies which we now describe as bacteria, bacilli, spirilla, and micrococci were then seen for the first time. Thus, the minute organ-

isms, to which in our day we attach so much importance, were first seen more than 200 years ago as small moving specks of matter.

So adept was Leeuwenhoek in the use of his simple lenses that for a considerable period other workers were unable to confirm his observations; but at last this was successfully accomplished by Trembley, in Geneva; by Baker, Hill, and Needham, in England; and by Schaeffer, Roesel, and Wrisberg, in Germany. It was soon observed that such organisms abound where putrefaction takes place, as in the scum that gathers on the surface of water in which animal or vegetable matter is macerating. The majority of observers thought they were of animal origin and called them animalculæ, but this was strenuously denied by Buffon, who held that they were merely particles of matter arising from the disintegration of previously existing matter, endowed with the property of movement, and termed by him "organic molecules." The question of the origin of these beings now took shape. Did they come from pre-existing living beings, or did they arise *de novo?* Some excellent observers—such as Réaumur, Joblot, and Hartsoeker—without definite experimental evidence, rightly supposed that they came from the air, and that they had dropped into the fluids in which they were found. Needham, a physician in this country, advanced a theory of spontaneous generation. He boiled beef infusion, placed it in a well-stoppered bottle, and found that it putrified. As boiling must have destroyed any animalculæ in the infusion, and as no others could have entered the tightly

stoppered bottle, he argued that the living beings which made their appearance must have owed their origin to a special vegetative force. He held that this force is a kind of energy, sometimes latent, but at other times, and in favourable conditions, calling new beings into existence.

This is the fascinating theory of abiogenesis or spontaneous generation. For many years it held its ground, and now and again it is revived but only to disappear under the criticism of severe experimental investigation. Few theories, however, have been more fruitful of great results to science inasmuch as it has stimulated research. Charles Bonnet criticised Needham's experiments by pointing out that the bottles he used could not be regarded as hermetically sealed, and by suggesting that, while organisms in the fluid might resist the temperature of boiling for a short time, they might not be able to do so for long periods. Spallanzani joined the controversy at this point, and, by a series of masterly experiments, upset the theory of spontaneous generation, or, at all events, rendered Needham's mode of expressing it untenable. He showed, first of all, that Needham was correct in his statement that living organisms always appear in boiled infusions introduced into stoppered bottles. He then found that they appeared even when the air was excluded from hermetically sealed flasks into which boiled infusions had been poured. Next, suspecting that the organisms might, in these circumstances, exist on the inner surface of the walls of the flask, he heated the flasks in a flame and then introduced the

infusion. Still organisms appeared. Surely, then, they must have entered with the air during the process of cooling. To test this supposition, he put infusions into flasks, hermetically sealed the flasks, and subjected them to the heat of boiling water for an hour. The result was that no organisms made their appearance in these flasks, but if the sealing was tampered with so that a few bubbles of air got into the flask, organisms were soon found. The conclusion was irresistible that living organisms, or their germs, or eggs, were necessary for the development of the putrefactive process. I have recently read critically the whole of Spallanzani's "Observations and Experiments on the Animalculæ of Infusions," and I find it difficult to believe they were performed one hundred and twenty-six years ago. He tests the influence of various temperatures; he meets the objection that the process he adopted must have altered the properties of the air in the flasks by showing that these properties were unaltered; he studies the effects of extreme cold, of various substances—such as oil of turpentine, fumes of tobacco, camphor, sulphur, "spirituous and corrosive" fluids, salt water, vinegar, milk, brandy, spirits of wine, and of electric shocks obtained from a "Franklinian battery." Further, he watches the modes of reproduction of such animalculæ, showing that some multiply by fission, and others by eggs or spores, and he observes that they vary somewhat in form according to their habitat and surrounding condition.

Since the time of Spallanzani, immense progress has been made in our knowledge of the life-history of those

organisms. We now know that their spores are floating in the air, but that if air be filtered before being allowed to enter a flask containing a sterilized putrefactive fluid, putrefaction never takes place. These organisms can now be separated from each other and cultivated in various media with as great accuracy, and with almost as great ease, as annuals or vegetables in a garden. We differentiate them more by their effect on infusions, or by their physiological action when introduced into a living body, than by their microscopical appearances; so that a practised eye can detect the presence of these organisms even without the aid of the microscope. Thus by cultivating them in gelatinous media, the form of the bubbles of gas and other changes in the gelatin often reveal the particular organism that produces these effects. Further, they have been named and classified, and the complete life-history of not a few has been followed through all its stages. All organic fluids, the soil, the air, the crumbling rocks, have been examined by the bacteriologist; their denizens have been brought out to the light of day, cultivated, and their physiological effects observed. This work is now carried on with microscopes as superior to the simple lenses of Leeuwenhoek and Spallanzani as the finest astronomical telescope is to a primitive pocket spyglass.

No one can over-estimate the important practical results that have flowed from the investigation of these minute organisms. The measures of modern hygiene by which contagious and infective diseases are at present kept in check and will be ultimately annihilated; the

economic results of the preservation of food; and the triumphs of antiseptic surgery, can all be traced back to the experiments of such men as Spallanzani. We now recognize that we are surrounded by invisible living things which, if allowed to work out their own life-history, are inimical to the lives of higher beings, including man. They have already slain their thousands and tens of thousands of human beings; and men, in their ignorance, have often attributed the dire effects of these minute organisms to direct interpositions of Providence. Now the intellect of man is asserting his supremacy, and by making himself acquainted with the life-history of these organisms, and with the conditions that favour or retard their development and growth, he is devising means by which his invisible foes must ultimately be defeated. Even in our own bodies we now know that there are conditions unfavourable to the development of these minute parasites. It would appear that we maintain a kind of standing army of living cells to resist the invaders, and the pathologists now tell us of sternly contested battles going on in our own tissues with details that read more like those of romance than of sober science. It is well to remember, however, that these minute beings are not all foes. Many of them play a beneficent part in the economy of nature. Without them dead organic matter would probably never disappear; possibly, the land, the air, the streams, and even the sea itself might become polluted; at all events the matter that had been transformed into organic compounds would be prevented from returning to the inorganic condition.

Silently they pursue their work of reducing complex organic compounds into those simpler bodies which are restored to Mother Earth, and thus these millions of workers—many of which are not larger than the one-fifty-thousandth of an inch—play their part in completing the organic cycle.

Let us pass to another subject that engaged Spallanzani's attention. In 1780 he published a series of important researches upon the digestive process. Before the days of experiment, the process of digestion was a fruitful subject for speculation and hypothesis. The oldest notion, attributed to Hippocrates, was taught by the Galenists for centuries. Digestion was regarded as a kind of "concoction," by which was meant a change such as occurs in certain substances when they are exposed to heat in closed vessels. Another notion was that digestion is a putrefaction. The food, according to this view, is broken down, and acquires a disagreeable odour in consequence of putrefactive changes. This hypothesis is also very old, and may be traced to the celebrated Roman author Celsus. Van Helmont, who flourished towards the end of the 16th century, first advanced what may be termed the fermentation theory. All digestive processes are fermentations, and the first fermentation occurs in the stomach. This was the theory held by Sylvius, Willis, Boyle, Grew, and Lower. It was somewhat modified by Boerhaave and Haller. It is curious that this old theory, which probably had its origin in the observation of gases being produced in the stomach, and in the frothy character of vomited matters

(resembling the froth recognized by old writers as significant of the fermentation of grape juice), should, in a different sense, be revived in the present day. A still later theory was that digestion is chiefly a mechanical process of trituration or breaking down of the food by the action of the teeth and by the walls of the stomach. This theory originated from the observation that many birds swallowed hard dry food, the comminution of which was attributed to the action of the gizzard. Up to this time, however, no accurate experimental work had been done. Such work was first attempted, in 1752, by the great French physicist, Réaumur. In his book *Sur la digestion des oiseaux* he described numerous experiments on the changes produced in food by the gizzards of fowls and the stomachs of various animals. Réaumur was thus the forerunner of Spallanzani, who, while he owed much to the suggestions of the French writer, investigated the subject with such thoroughness as practically to begin a new epoch in the history of the subject. Spallanzani's methods were experimental, and he had many of the highest qualifications of a scientific worker. In reading an account of his experiments, one is struck with the natural sequence of his observations. Sometimes failures in obtaining results which he expects may dishearten a scientific worker, or, at all events, turn him aside from the path he was hitherto following. This was not the case with Spallanzani. He soon discovered the cause of failure either in his method of working, or in the theory that prompted the particular experiment. Spallanzani's work is one of the best examples in science of the combined

method of deduction and induction. He did not collect a mass of facts at random, nor even by the continuous application of one mode of inquiry. The investigation was never prompted by mere curiosity. Theory indicated the line of research; and, frequently, as is the case with men of true scientific insight, the facts obtained were in consonance with the theory. This play and interaction between theory and experiment is one of the most striking features of Spallanzani's researches.

He first refers to the experiment of Réaumur, in which he caused birds to swallow metallic tubes, open at both ends, and containing grains of wheat or maize. Réaumur found that when the animals were killed some hours afterwards and the tubes taken out of the stomach, the grains of barley were entire, "whence he inferred that in birds of the gallinaceous class the food is not broken down by a solvent, but by muscular action." Spallanzani repeated these experiments; and, by using grain removed from the "crop" of fowls, and therefore partially macerated, and by placing it in globes of brass, half an inch in diameter, and perforated like a sieve, he demonstrated that solution then took place. He then proceeded to make experiments on the power which ducks, fowls, and pigeons have of pulverizing, by the action of the gizzard, hollow glass globules or solid glass balls—experiments previously made, however, by the celebrated naturalists, Redi and Vallisnieri. Spallanzani also found that, whilst the stones in the gizzards of many fowls assisted in the comminution of hard matters, they were not absolutely necessary, and that the trituration was the

immediate effect of the muscular walls of the gizzards. In his experiments on pigeons, turkeys, and geese, by causing the birds to swallow a piece of clean sponge, he obtained a fluid, and he showed, further, that when this fluid was placed in a tube with small bits of mutton or bruised grains of wheat, and was kept warm, the meat alone was dissolved. It is curious to notice that the method he adopted for keeping the tubes at the proper temperature was to carry them about in small pockets in his armpits for several days. There were no gas regulators in those days, so he was obliged to resort to a simple but efficient method by which the tubes were kept at a fairly uniform temperature.

He then proceeded to investigate digestion in a similar manner in crows—apparently the grey or carnivorous crow—and he obtained evidence that the digestion of flesh given to these birds was proportional to the amount of gastric juice secreted. He also caused his crows to swallow sponge, which could be drawn back again, and with the fluid thus obtained, he succeeded in digesting meat. By carrying on experiments at different temperatures, he demonstrated the importance of heat in digestion, and proved that the process was carried on with greatest efficiency at a certain mean temperature. Time will not allow me to describe his experiments on herons, frogs, newts, snakes, fishes, sheep, oxen and horses; but I may say that those on sheep and oxen are specially important, as, with the exception of a few observations previously made by Réaumur, they were the first to give any accurate information regarding the process of diges-

tion in ruminants. After quoting Réaumur regarding the digestion of animals having membraneous stomachs, from which the French observer justly inferred that digestion was produced by the gastric fluid without the concurrence of any triturating power, Spallanzani made numerous experiments on owls, falcons, eagles, cats, and dogs, and finally he concluded the investigation by experiments upon himself. He swallowed masticated bread enclosed in bags and found that the bread disappeared. Becoming gradually courageous in this dangerous kind of physiological investigation, he swallowed tubes enclosing morsels of meat, membrane, tendon, cartilage, or tender bones, and he found that the human stomach digested food without much trituration. Further, he went through the very disagreeable ordeal of evacuating the contents of his own stomach, by which he obtained a sufficient quantity of a fluid which had the power of digesting meat in glasses kept at a uniform temperature.

These experiments showed clearly that digestion depended partly upon trituration, partly upon the chemical action of the gastric juice, and partly upon heat. Spallanzani denied that any kind of fermentation or putrefaction occurred, and asserted that digestion was essentially a chemical process which might be imitated in the laboratory.

Since the time of Spallanzani our knowledge of the digestive process in the stomach has become singularly extensive and accurate. We are acquainted with the structure of the glands that secrete the juice, and the changes which

occur in the secreting cells lining the glands have also been studied. The fluid has been analyzed, and the physiological properties of its active principle, pepsin, and of its most obvious constituent, hydrochloric acid, have been elucidated. Spallanzani's conclusion that digestion in the stomach is a chemical process has been confirmed, but the exact nature of the chemical operations is still obscure. The pepsin belongs to a remarkable class of bodies known as ferments—substances which have the power of initiating molecular changes in organic matters without their own molecular structure being affected. Thus pepsin, in league with hydrochloric acid, acts on albuminous substances so as to form hydrated bodies called peptones. These peptones, however, do not simply pass into the blood as peptones, but they are seized by the epithelial cells covering the mucous membrane of the stomach and are again dehydrated to form the serum albumin of the blood. It would seem that the action of the pepsin and hydrochloric acid is to prepare suitable food-stuffs for the living cells that line the stomach and intestines. These cells alter chemically and physically the substances thus absorbed, and then, in obedience to a law not yet known, they pass them on to the blood. The chemico-physical processes are modified by the fact that they occur not in dead membranes but in living cells. The action of the protoplasm of the living cell is an important and still a largely obscure factor in these remarkable transformations. We have got far beyond the facts first ascertained by Spallanzani, but our advances have only brought us

face to face with more profound problems. We are now more concerned with the molecular machinery of vital actions than with the obvious and larger movements of the mechanism. It is significant of the present state of physiological science that we are not so sure of some departments of our knowledge as we were twenty years ago. We are not now satisfied with superficial physico-chemical explanations, because we find that phenomena which are apparently physico-chemical are very unlike phenomena of a similar kind occurring in the arena of dead matter. The physiologist of the present day believes that all such phenomena are really molecular—physico-chemical—but he has also realized that the conditions of living matter are in many respects unlike those of dead matter, belonging, as it were, to a different plane, and that he is yet far from an ultimate explanation. The swing of the pendulum is at present in the direction of a modified form of vitalism.

Time will not allow me to do more than refer to other great researches carried on by the Italian physiologist. He was one of the first to investigate the obscure phenomena of fecundation, and to observe the facts that led to the theory of parthenogenesis. He repeated and extended the observations of Redi and others on the regeneration of the limbs and other organs of crustacea after these had been artificially removed. He studied the phenomena of hybernation and the curious state of lethargy produced in many animals by a cold and dry atmosphere. Viewing life as the result of a molecular mechanism, it is conceivable that the operations of the mechanism might

simply be arrested, and that if the body were then protected from disintegrative agencies, it would remain unchanged for an indefinite time. If we could then start the mechanism afresh, by returning to the former conditions, life would be restored. Many of Spallanzani's observations pointed to this strange conjecture. By the careful withdrawal of heat and moisture one function after another is suspended until there is apparent death ; but on renewing the first conditions, life again goes on. Such experiments can be performed on certain animals, and if they could be performed on man, he might be sent to oblivion for a century and then revived, like Rip-van-Winkle. This may appear a wild dream, but it is quite in harmony with the molecular theory of life, and it is supported by many curious facts, some of which were first observed by Spallanzani.

The last, and perhaps the most important, of the physiological researches of Spallanzani were on the intimate phenomena of respiration. It is a striking fact that many fundamental physical and chemical discoveries have originated in physiological research. The investigations of Galvani led to the wonderful development of galvanic and voltaic electricity that we see in our own day. Mayer attacked the problem of the transformation of the physical forces from a physiological standpoint. The theory of respiration has also led to epoch-making investigations and to great practical results. Mayow, towards the close of the 17th century, came near the discovery of oxygen during his investigations into the changes produced in air by breathing; and a century later

Priestley re-examined this question with great success, and finally made his famous discovery of oxygen. He showed that the air lost oxygen by breathing, and soon afterwards Lavoisier proved, by actual weighing, that it gained carbonic acid, although the fact that "fixed air," or carbonic acid, is produced by breathing had been observed by Joseph Black twenty-three years before the date of Lavoisier's celebrated experiment. Then arose the question of What is respiration? According to Lavoisier it is a slow combustion of carbon and of hydrogen. The air supplied the oxygen, and the blood the combustible matter. The great French mathematician Lagrange pointed out that such a combustion would produce heat, and if combustion occurred in the lungs alone, as was then the prevalent opinion, the temperature of these organs would become so high as to destroy them. He therefore hazarded the conjecture that the oxygen is simply dissolved in the blood, and in that fluid combines with carbon, forming carbonic acid, which is then set free in the lungs.

Spallanzani's researches threw light on this problem. They were conducted with the scrupulous care and exactitude that characterized his other work. He appealed to nature by many ingenious experiments. He made the discovery that snails and other molluscs immersed in an atmosphere of hydrogen or of nitrogen exhaled carbonic acid to almost as great an extent as if they had breathed air. Note the importance of this observation. It proved that the blood gave off, for a

short time, at all events, carbonic acid, even in the absence of oxygen. Further, Spallanzani showed that many animals absorb oxygen and give up carbonic acid by the surface of their bodies without the action of either lungs or gills. He also demonstrated that even tissues breathe, a bit of muscle exhaling carbonic acid and consuming oxygen. He proved, by quantitative experiments conducted with much skill and accuracy, that the amount of oxygen absorbed and of carbonic acid exhaled depends on the degree of activity of the body as a whole, or of the particular tissue. By cooling the animals, and thus retarding the vital processes, he could diminish the amount of carbonic acid formed. He was also the first to show that respiratory combustion may be influenced by the nature and quantity of the food. All these researches demonstrated that the union of oxygen with carbon does not occur in the lungs, or even in the blood (except to a small extent), but in the tissues; and they paved the way for the modern generalization that each element of tissue has, in a sense, a life of its own, selecting from the nutrient and respiratory blood oxygen and suitable pabulum, and giving up carbonic acid and other waste products. The conception of a combustion or burning is very crude. No doubt it is in harmony with the known facts relating to the absorption of oxygen and the production of carbonic acid; but a more careful study of the phenomena occurring in living matter leads irresistibly to the conclusion that respiration of tissue is not so simple as a combustion, but is more akin

to the phenomena of fermentation. Here again we have penetrated far beyond the standpoint of the Professor of Pavia.

In reading over the record of Spallanzani's work, one cannot but be struck by the absence of two great ideas which in our day dominate and direct scientific thought. The first is that of the permanence of matter and the second is that of the permanence of force. Man had not, in Spallanzani's day, reached the profound conception that all the phenomena of nature, as seen on our earth, and including among these all the phenomena of life, depend upon interchanges of the elements of which the earth is formed. Nor had the corresponding thought arisen that while the various forces may apparently disappear they reappear under new forms; in other words, that the sum of energy is always the same, and no force, no more than an atom of matter, is destroyed. These ideas, gentlemen, you will find running, like golden threads, through all your studies; or, to vary the metaphor, they are the keys by which you will unlock the store-houses of knowledge. They were almost unknown to the Italian Philosopher. They may have arisen like dim lights on the horizon of his thought; but many years had to pass before they became the beacons of science, radiating into all the dark regions of the universe. In no department have they been more potent than in Physiology, and the outcome of it all is that the votaries of this science now hold that no life exists without change of matter, and no life manifests itself without change of force.

Such were the chief researches of Spallanzani. A sketch of his career has perhaps given you some insight into the nature of the studies in which you will be engaged in your medical curriculum, and at the same time it may have shown you how much may be achieved in one lifetime of earnest and hearty labour.

You are already, or you are about to become, students of nature, and you will be called upon to take your share in the work of investigation. In a true sense, every student is an investigator. Your knowledge is not to be derived only from books. You will be brought face to face with natural phenomena, and you will be asked to interrogate these for yourselves. Your teachers will all strive so to present knowledge as to call forth your powers of making it your own. You should note each fact brought before you, and each experiment demonstrated in your presence, as if you were personally observing the fact and making the experiment. Like Spallanzani, be accurate, methodical, and truthful in all your work. Science is the truth about things. A scientific training teaches us to discriminate between what is real and what is apparent. It brings us face to face with things as they really are. Your education will not consist merely in acquiring a knowledge of certain facts. It is more correct to say that it will be a discipline. I know no education which has a wider or grander sweep than that of a student of medicine, nor one more fitted to call forth all the powers of a strong and healthy mind. Let me, in conclusion, wish

you much success and happiness in your studies, and a share in all those influences that build up a manly character—influences which can only be enjoyed, in their fullest measure, in an ancient and famous University like our own.

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